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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Lubrication of the
Low Speed Diesel

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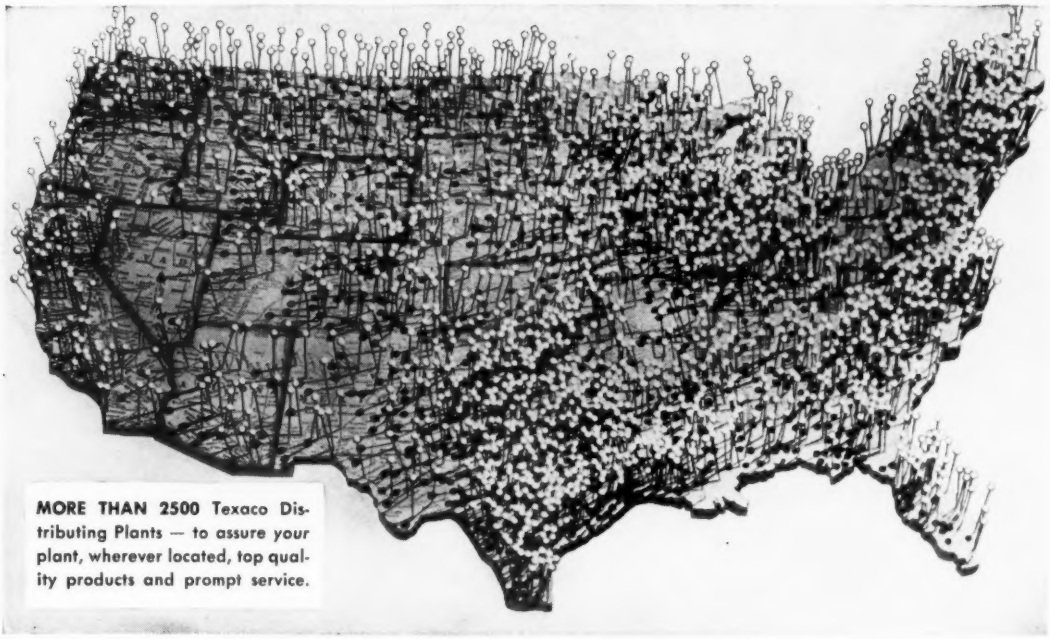

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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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Lubrication of the Low Speed Diesel

THE old lumbering large low speed Diesel has become, as a result of over 50 years' development, a highly efficient, skillfully engineered, precision-built machine, having a flexibility that permits the utilization of a wide range of gaseous or liquid fuels. Just as Paris was the style center, before the war good practice as regards Diesel design also originated in Europe where the majority of these large Diesel engines were produced. Then the situation changed. The American Diesel engineering fraternity was more than equal to the occasion and created distinctive, well-engineered designs which are a credit to American Industry.

As is often the case when mechanisms become more efficient, they require special lubrication attention. The Diesel lubrication engineer, therefore, during the past several years has been faced with many new problems, largely resulting from the development of more and more power and heat in a given size cylinder; see Table I. At first, he met these problems by borrowing from European practice, leaning rather heavily on his overseas associates. This soon proved inadequate, however, and it became necessary to make a thorough study of Diesel lubrication and develop new lubricants and lubrication procedures to keep pace with the rapid strides of the Diesel in this country.

FIFTY years ago, farsighted Adolphus Busch brought Dr. Diesel's invention to this country and thus created one of our leading industries. It is no secret that the going has been rough in spots, however, each fuel and lubricant problem has been attacked and solved with the cooperation of the builder, the user and the lubrication engineer. Out of this work, a reliable, efficient machine has emerged, and a foundation of fundamental lubrication knowledge has been established.

As one of the largest operators of Diesel engines and suppliers of Diesel lubricants, The Texas Company has actively participated in this development, and on this 50th anniversary of the American Diesel, takes this opportunity to summarize some of this experience. It is hoped that such information will help solve new problems as they arise, while this great industry moves forward.

Lubricating a large Diesel is primarily a case of preventing ring wear and promoting piston cleanliness. Not only are these two requirements interdependent, but both are influenced considerably by fuel combustion products. The problem can become complex and successful operation requires a working knowledge of the factors involved, so that in case of any difficulty the specific cause can be isolated.

Most engine deposits originate from products of incomplete combustion of the fuel or from deterioration of the lubricating oil. In attacking the problem of deposit formation, it is advisable to first make sure that all operating conditions necessary for complete combustion are complied with. Assuming for the moment that this has been done, it is then necessary to consider the factors influencing oil deterioration. These include the oxidation resistance, evaporation and dispersion characteristics of the oil, the temperatures in the engine, and design factors influencing the length of time the oil is subjected to high temperature.

Oxidation—Oxidation, the combining of an oil

TABLE I

Increase in Rated Power Output of a Popular Large Two-Cycle Diesel 1928-1948

	Horsepower per Cylinder
Before 1928	120
1928-1930	140
1930-1932	150
1932-1934	160
1934-1944	175
After 1944	200

molecule with oxygen, becomes appreciable at temperatures over 200°F; it is accelerated at higher temperatures. Time is a very important item, however, as shown in Table II. It will be noted that an oil exposed to 400°F for 1½ hours was oxidized as much as at 300° for 45 hours.

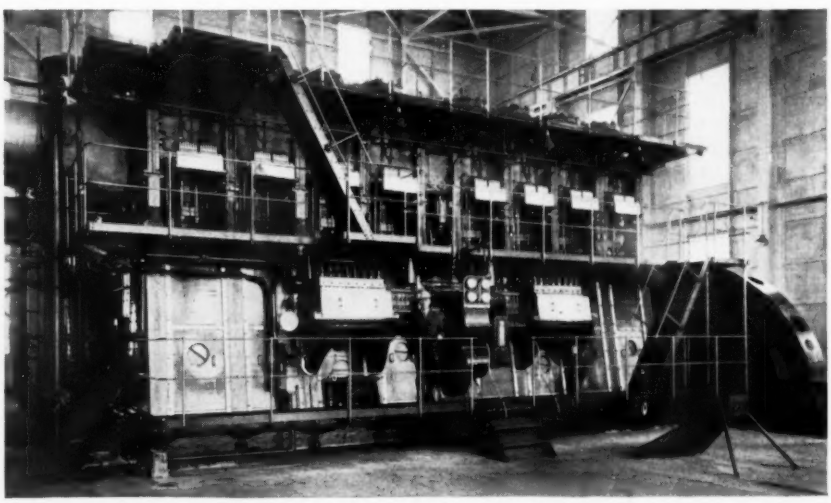
catalytic effect of copper on oxidation. Such oils should receive consideration if the cylinder oil comes in contact with copper or bronze piping or bearing metal.

Water—Water also promotes oxidation, as shown in Table IV. Normally, little oxidation takes place under 212°F, but if water is present, considerable oxidation may occur at even lower temperatures. Care should be taken to keep water drained from oil tanks and jacket temperatures should be maintained above 130°F to prevent condensation of water, one of the products of combustion, on the cylinder walls.

Inhibitors—To reduce piston deposits, the oil may be fortified with an oxidation inhibitor. This will increase the oxidation resistance of the oil. However, it must be remembered that any oil, regardless of its type or how well fortified, will eventually form a deposit if left long enough as a static thin film at the temperatures existing on piston surfaces.

Detergents—To improve engine cleanliness, de-

Courtesy Lima-Hamilton Corporation



7,000 HP
8 Cyl.
24x36
167 RPM
2 Cycle
Double Acting

When hot oil is exposed to air, the oil at the surface is most rapidly oxidized. The products of oxidation at first remain dissolved in the oil and the oil darkens. As their concentration increases, some precipitate as fine particles which eventually coagulate and drop out, forming deposits.

Oil Film Thickness—The thickness of the oil film is one of the important factors determining the concentration of oxidation products. It is quite obvious that a thin film of oil will have a greater percentage of its molecules exposed to the air and a lesser quantity of oil available to hold the oxidation products.

Catalysts—The presence of certain materials known as catalysts accelerates oxidation. Copper is an active catalyst and, so is iron but to a lesser extent; see Table III. Certain of the detergent oils contain catalyst poisoners which greatly reduce the

tergent additives are incorporated in lubricating oils. The effect of detergents in preventing the depositing of an oil's own oxidation products is not as great as it is in removing or preventing deposits from another oil or fuel. This means that detergent oils are used as cylinder lubricants most effectively where

TABLE II

Relationship of Temperature and Time for Same Degree of Oxidation (Based on MacCoull test)

Temperature °F	Hours
300	45
350	8
400	1½

TABLE III

Catalytic Effect of Copper on Corrosion due to Oxidation of a Straight Mineral Oil
(Based on MacCoull test)

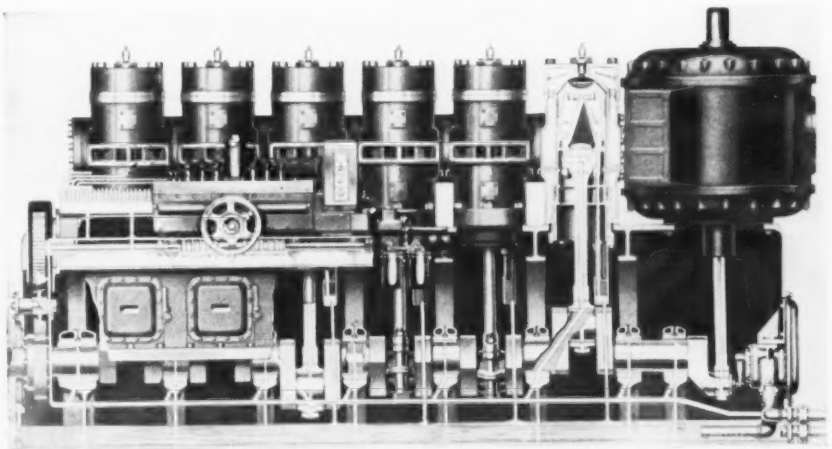
Hours	Copper-Lead Bearing Weight loss, mg. at 350° With Steel Baffle	With Copper Baffle
0	0	0
2	2	5
4	3	75
6	15	155

potential piston deposits originate from the fuel or from a different crankcase oil. Detergent oils are least effective in large cross-head type Diesels operating on a good fuel. Most of the heavy duty detergent oils are made from relatively non-volatile base stocks and numerous cases are on record where cleaner engines have been obtained using a more volatile straight mineral oil. In fact, it is quite well established that in many large 4-cycle engines detergents have little effect and that piston cleanliness is improved by using an oil which evaporates or burns away cleanly with very little residue.

Volatility—Volatility, which is just another way of saying boiling range, is usually expressed by a distillation curve of the oil. Table V shows the average boiling point and the actual rates of evaporation for two oils. It will be observed that the more volatile oil forms the least deposits but gives greater wear and higher wall temperatures under severe operating conditions. The lubricant for a given set of cylinders, therefore, should be sufficiently non-volatile to remain on the cylinder surface long enough to provide a lubricating film until it is replaced and yet be sufficiently volatile to evaporate before it oxidizes to form lacquer or carbonaceous matter. To select an oil for a given design requires a knowledge of the volatility and other oil characteristics, temperatures and other engine data, and above all a background of successful experience.

Temperature—The amount of deposit an oil forms on a hot surface depends on whether oxidation which is tending to create deposits prevails over evaporation and mechanical factors tending to remove the oil. The effect of temperature on the amount and nature of deposits varies with different oils. Up to a certain temperature the deposit is light and easily removed with solvents. Above this critical temperature, the deposit is largely carbonaceous and must be scraped or burned off. The critical temperature for most oils lies between 400 and 600°F. Applying this knowledge of the reaction of oil at higher temperatures, there are several steps that can be taken to reduce the formation of piston deposits. For example, a more volatile oil may be used. This means either changing to a lighter grade of the same oil or to a different type of oil. The limiting factor here is the greater tendency of the more volatile oil to permit wear.

Generally speaking, from an oil deposit standpoint, lowering piston temperatures decreases both piston skirt lacquer and ring sticking, although there are cases where higher temperatures have moved the critical temperature zone, at which maximum carbon



Courtesy
Fairbanks, Morse & Co.

1,200 HP
6 Cyl.
16x20
300 RPM
2 Cycle

TABLE IV

Effect Water on Oil Oxidation
(Modified Indiana test)

	Neutralization Number after heating for 120 hrs. at 205°F with copper-iron coil
Without Water	0.5
With 20% Water	1.9

TABLE V

Characteristics of Relatively Volatile and Non-Volatile Oils

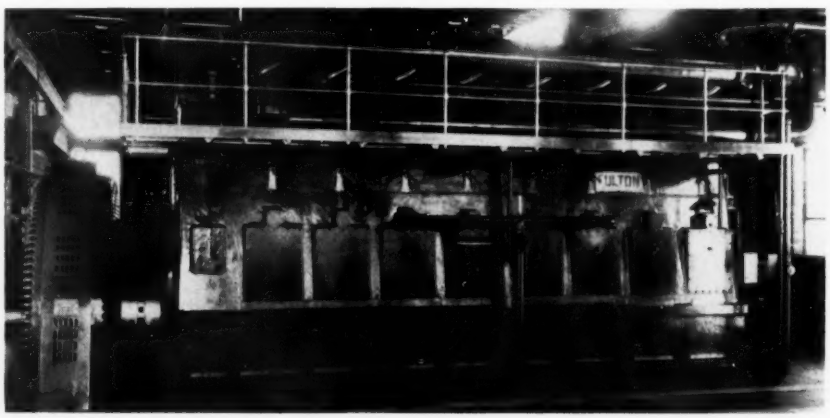
	Relatively Volatile Oil	Relatively Non-volatile Oil
Wear—Avg. Ring Weight Loss, g., after 24 hours at 250°F. jacket temperature.	3.1	1.2
Deposits—Thin film residue, %, after 24 hours at 450°F.	4	13
Liner Temperature °F, top of ring travel at 250° jacket temperature	465	420
Oil Characteristics, Average Boiling Point °F.	760	890
Viscosity, centistokes at 450°F.	1.1	1.4
Evaporation at 450° mg/sq cm/hr.	25	11

done by the engine designer to reduce piston temperatures. There are engines, for example, which have been supercharged with no increase in piston cooling or piston sealing. Table VII shows the affect of supercharging on heat balance. Even though it is eventually converted to power or swept out the exhaust, the additional heat released in the combustion chamber raises piston temperatures as noted in Table VIII, which shows the affect of supercharging on piston temperatures and blowby. Both accelerate deposit formation.

Oil Flow—Piston skirts should be kept as cool as possible to reduce the possibility of oxidation and lacquer formation. The temperature of the piston skirt is usually in the neighborhood of 250° F. While the oil film on the piston skirt thickens due to oxidation, it still remains liquid and is easily removed unless it becomes overheated by shutting the engine down too quickly, in which case it becomes hard, black and brittle. If the film is allowed to remain too long during operation, it becomes a black scum which promotes ring sticking.

Courtesy
Fulton Iron Works Company

1,800 HP
8 Cyl.
17½x24½
277 RPM
4 Cycle



is formed, away from the important top ring.

Unfortunately, from a lubrication standpoint, piston temperatures appear to be increasing. Much progress has been made in obtaining more power from a given size engine. This has been accomplished in two-cycle engines by increasing the piston speed as shown in Table VI. In four-cycle engines, supercharging has boosted power output considerably. The combustion of a considerably larger amount of fuel in a given time has correspondingly increased the amount of heat released in the engine. Part of this heat has been removed by better cooling, but there has also been a significant increase in the temperature of engine parts near the combustion chamber. Pistons, which formerly were sufficiently cool so that excessive oxidation of the oil did not occur on their surface, are now hot enough to cause some oils to deteriorate and form deposit.

Although much has been done, still more can be

It is important, therefore, that the heavy, partially oxidized oil which coats the piston skirt be continually removed. This may be accomplished by

TABLE VI

Large Diesel Comparison
1915-1947

	Cyl. Size	RPM	HP/Cyl	HP/ Cu.In. Displ.	Piston Speed
(Based on "Diesel Engines—AH Goldingham 1915)					
Sulzer	18.5x26.8	150	225	.031	670
MAN	23.6x36.2	120	337	.021	725
Carels	20.1x30.2	130	266	.028	655
(Based on "Diesel Engine Catalogue" 1947)					
Busch Sulzer	20.5x27.5	240	340	.038	1100
Hamilton	21.5x27.5	240	375	.038	1100
Nordberg	21.5x29	225	400	.038	1090

TABLE VII

Effect of Supercharging on Heat Balance—Large 4-Cycle Diesel

Percentage Basis

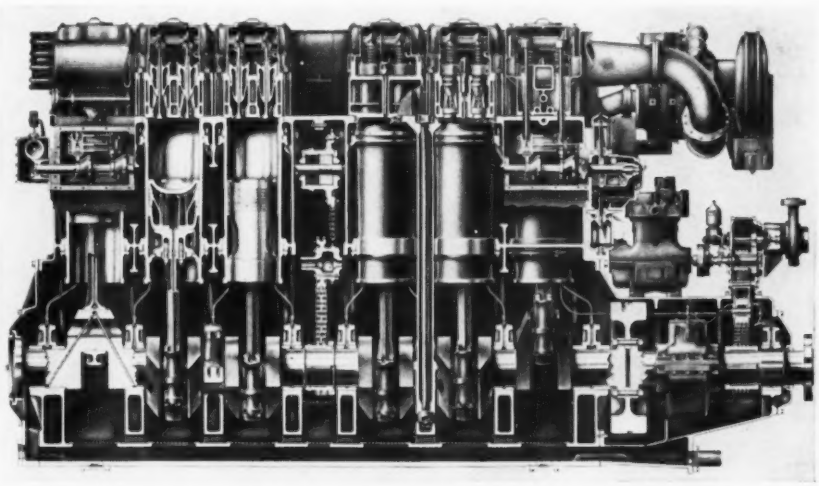
Total Unsupercharged Heat Output = 100

	Unsupercharged	Supercharged
Shaft Output	36	50
Exhaust	34	57
Cooling Water	25	21
Oil Cooler	3	4
Radiation	2	2
Total	100	134

installing rings in the lower part of the cylinder which scrape the oil off the piston skirt into a sludge pocket. Injecting fresh, clean oil from a separate mechanical lubricator into the cylinders near the top of the ring travel also aids in keeping the oxidized oil from the piston skirt from reaching the ring belt area.

One way to prevent deposit formation is to increase the rate of circulation of the oil over the hot area. This can be done by feeding more oil, but any gain in circulation rate attained by this method is more than offset by increased carbon in the combustion zone. The combustion chamber is so hot that a fair percentage of all excess oil is converted to carbon. In other words, increasing the oil feed may reduce deposits in one area, but increase them in another. Therefore, to keep overall deposits down, the oil feed and consumption should be held to a minimum consistent with wear considerations. Sludge chambers at the base of the cylinder and holes in the piston behind wiper rings do, however, improve circulation without forcing excess oil into the combustion zone.

Wear—As engine temperatures increased, a tendency for cylinders to run dry and wear out at the top of the ring travel was noted. In studying this problem, it soon became evident that the critical factor (K) is the amount of power developed per square foot of new oil film generated. In other words, $K = \frac{HP/Cylinder.}{\pi DLN}$ Where D and L equal the bore and stroke in feet and N equals engine RPM. For example, it was found that an oil which had been used satisfactorily for years in a certain line of engines, started giving trouble when K exceeded .045. This critical K value, which of course varies with different oils and engines, is very useful in determining in advance the type of lubricant required for a specific installation. This, of course, is an admission that no one single oil can be considered ideal for all engine types and operating conditions. This is emphasized when considering the question of volatility as already explained.



Courtesy
The Cooper-Bessemer Corporation

1,180 HP
6 Cyl.
15½x22
327 RPM
4 Cycle

The effect of viscosity on wear is shown in Table IX. From these data it may be concluded that an oil for cylinder lubrication of large Diesels should exceed 50 SSU Viscosity @ 210°F. Most manufacturers specify 60 to 70.

While the lubrication engineer can frequently

TABLE VIII

Effect of Supercharging
Typical Small Engine

Supercharge Pressure, in. Hg	0	10	20
BMEP	85	122	155
Top Ring Groove Temperature, °F.	395	456	466
Blow-by, CFH	13	26	40

TABLE IX

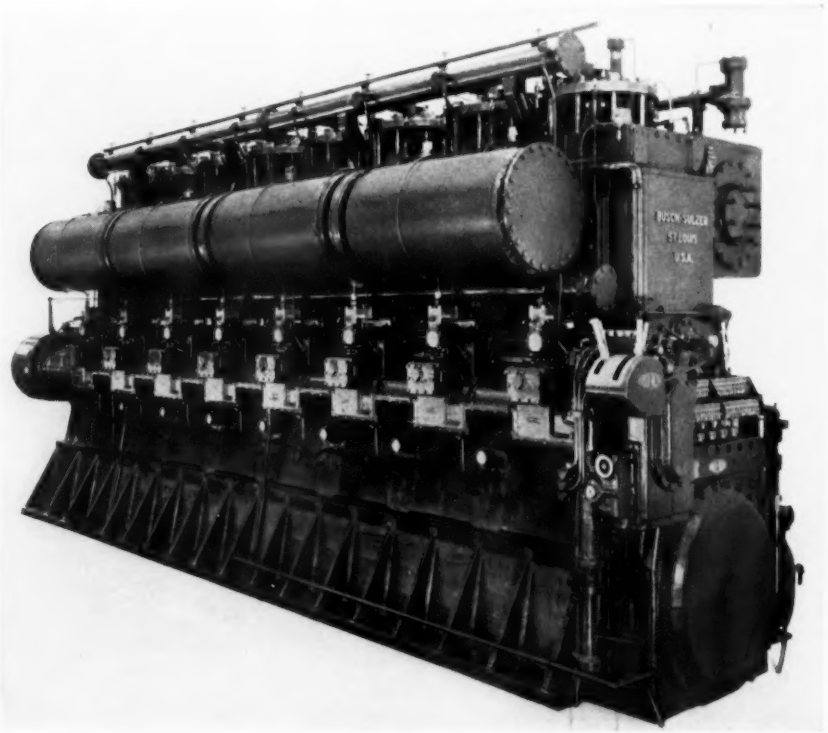
Effect Viscosity on Piston Ring Wear. Small 2-cycle Diesel at 300° Jacket and 430° Cylinder Wall Temperature (at top of Ring Travel) using Paraffin Base Oil, and Low Sulphur Fuel.

Oil Viscosity SSU at 210 F	Wear Ring weight loss, g.
45	9.0
50	3.4
60	1.4
70	0.9
80	0.7
90	0.5
100	0.5

to protect against wear. Certain additives increase the power of the oil to adhere to metallic surfaces, preventing rupture of the oil film. Others serve as anti-welding agents, preventing the fusion and scuffing which would otherwise occur should clean, metallic, surfaces come in sliding contact under sufficient pressure.

Other additives indirectly prevent wear by protecting against corrosion at low temperatures. Still other additives prevent the natural tendency of oils to creep away from hot surfaces.

It has also been shown that certain oils form deposits, usually on the piston crown above the top ring, which are abrasive to soft steel. Such deposits may cause vertical scratching of cast iron piston



Courtesy Busch-Sulzer Bros.-Diesel Engine Division of the Nordberg Manufacturing Company

2,720 HP
8 Cyl.
20½x27½
240 RPM
2 Cycle

reduce wear by supplying a less volatile oil, this is at the expense of a greater tendency to form deposits. Accordingly, the designer has cooperated by improving the distribution of oil to the upper part of the cylinder which has been accomplished by fitting the oil leads here and by using piston rings which carry more oil to this zone. Engines which adequately distribute oil to the top of the ring travel can be lubricated with a more volatile oil and benefit greatly from a cleanliness standpoint.

In addition to controlling wear by using base oils of proper viscosity and volatility, additives can be incorporated which increase the ability of the oil rings. Excessive clearance between the top of the piston and the cylinder wall will contribute to this type of wear.

TABLE X

Effect of Sulphur Content of Fuel on Corrosive Engine Wear

Jacket Temperature	Average Ring Weight Loss gms. per 12 Hour Period Low Sulphur Fuel	High Sulphur Fuel
80°	.32	.80
300°	3.09	3.08

TABLE XI

Effect of Sulphur Dioxide on Oxidation
(Indiana Oxidation Test)

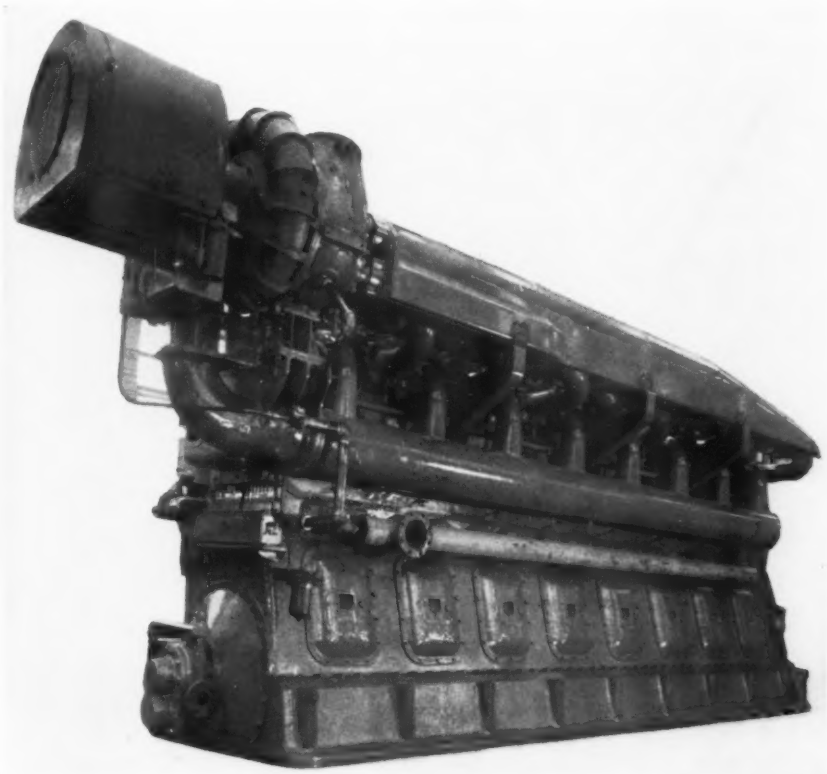
Gas	Hours to form 0.1% Sludge
100% Air	480+
75% Air, 25% SO_2	85

Fuel—While higher engine temperature has given rise to deposit and wear problems associated with lubrication, it has reduced deposits and wear resulting from fuel combustion products. At higher temperatures combustion is more complete and condensation products are largely eliminated. In any study of lubrication of internal combustion engines, consideration must be given to the important effect fuel has on engine deposits and wear. The fuel characteristics involved in this connection are viscosity, carbon residue, water and sediment, distillation, cetane number, and sulphur content.

Since poor atomization causes poor combustion, it is desirable to control the size of the fuel droplets injected into the combustion chamber. The viscosity of the fuel will determine the size of the fuel droplets for a given orifice and pressure. Viscosity, in turn, can be controlled by varying the fuel temperature. This requires heating the fuel, if necessary, to keep the viscosity under 150 SSU.

There is a limit beyond which fuel should not be heated. Most fuels can be safely heated to 180°. Above this temperature heater fouling is apt to be serious and volatilization may occur. Preheating the fuel also accelerates gum formation in the injector. This can, however, be controlled by proper cooling of the injector either by water jacketing or by circulating a large amount of excess fuel back to the fuel tank.

Carbon residue is a test in which the fuel is burned under controlled conditions and the residue determined. Most large Diesels can satisfactorily



Courtesy
Worthington Pump & Machinery
Corporation

1,760 HP
8 Cyl.
16x20
360 RPM
4 Cycle

TABLE XII

Typical Fuel Oils Used in Diesel Engines

	A	B	C	D
Gravity, API	13	16	23	27
Flash, °F	210	200	190	110
Viscosity SSU at 100°F	1700	515	100	50
Viscosity SSF at 122°F	75	28	14	13
Temperature for 150 SSU, °F	175	145	80	35
Carbon Residue %	11	9	6	2
Sulphur %	2.0	1.3	1.2	0.5

burn fuels with carbon residues up to 4% and under favorable temperature over 10%. Carbon craters on the injection nozzle tips usually indicate that a high carbon residue fuel is in use and these craters should be removed before they interfere with the fuel spray. Since carbon residue is a decomposition product of liquid petroleum, it cannot be reduced appreciably by filtration of the fuel.

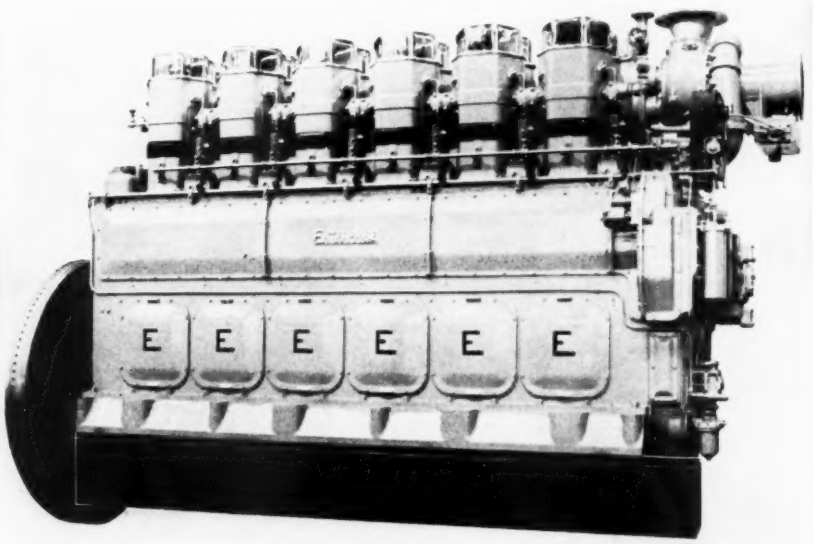
Water and sediment, however, are foreign materials that can be removed by proper fuel purification. Centrifugal purifiers are more generally used and will effectively remove water and sediment.

Tests have shown that poor combustion, as evidenced by smoke, is a function of the Cetane No. and the distillation characteristics. The Cetane No. measures the ignitability and distillation, the volatility; both combining to indicate the relative soot forming properties of the fuel.

dioxide in water condensed on cylinder walls. At high temperatures, this corrosive wear does not occur.

The high temperature data in Table X was obtained using a fairly volatile oil and very hot cylinder walls so that any corrosive products formed would have ample opportunity to attack the relatively dry ring metal. Even under these conditions, although the engine was sensitive to wear, as shown by the high weight losses, no evidence of corrosion due to sulphur at high temperatures was found.

It has been reported by several investigators, however, that sulphur does give difficulty under high temperature operating conditions by accelerating deposit formation causing increased abrasive wear. Such deposits are often easily removed by soap and water which will not touch ordinary petroleum decomposition products. The accelerating effect of sul-



Courtesy
Enterprise Engine & Foundry Company

1,300 HP
6 Cyl.
16x20
375 RPM
4 Cycle

Large Diesels have burned high sulphur fuels for years with no difficulty, provided the sulphur is combined in a non-corrosive form. This latter point may be ascertained from the results of the copper strip corrosion test.

Even the non-corrosive forms of sulphur, however, cause corrosion if engine jacket temperatures are so low that water condenses on the cylinder walls during operation. The sulphur burns to SO_2 which in turn dissolves in any water present forming corrosive sulphurous acid which can cause rapid cylinder wear. The effect of sulphur on cylinder wear is illustrated in Table X, which shows the results of repeated engine tests of low and high sulphur fuels at low and high temperatures. At low temperatures, high sulphur fuels result in wear from corrosion by sulphurous acid formed by absorption of sulphur

phur dioxide on oxidation, shown in Table XI, may explain in part the increased deposits formed from high sulphur fuels.

Since there is every evidence of an increasing supply of high sulphur fuel, this problem is under considerable investigation at the present time. Already, ways of overcoming the disadvantage of high sulphur have been developed by the metallurgist, the engine designer and the lubricating oil manufacturer.

There has also been a definite trend toward the use of heavy fuel oils in large Diesels. The variations in fuels available are shown in Table XII. A and B are heavy fuel oils. C is a light bunker fuel and D is a topped crude. The high speed Diesel operates well on the distillate fuels, lighter than those tabulated, and the larger Diesels have little difficulty digesting

the light bunker fuel. The heavy fuel oil is, however, a real problem, but good progress in the handling of such fuels is being made. The heavy fuels require good purification, heating equipment, well-cooled injectors, good atomization, hot combustion chambers and detergent or heavy duty lubricating oils.

To burn the very heavy fuels, it also is usually necessary to increase injection pressure and intake air pressure. Extreme care must be taken to make sure jacket temperatures are always maintained high enough to insure good combustion. It is also advisable to switch to a lighter fuel whenever it is necessary to operate at light loads, and when starting and stopping.

Tests have shown that changing from a light to a heavy fuel increases exhaust temperature, fuel consumption and lubricating oil purifier deposits.

Mechanical Lubricator Fluid—Detergent oils have proven effective in preventing deposits of soot and other combustion products from adhering to engine parts. Before the detergent oils could be used in large Diesels, it was necessary to develop special fluids for the sight glasses of liquid filled mechanical lubricators. When detergent oils are used with water or glycerine, the lubricator solution may become cloudy, be carried over with the oil or affect drop formation due to additive action. Some natural waters and certain commercial glycerines fortuitously happen to contain impurities which prevent their going into solution with detergent oils. Ordinarily, however, small quantities of a special powder must be added to distilled water to make a lubricator solution which will be satisfactory for use with detergent oils.

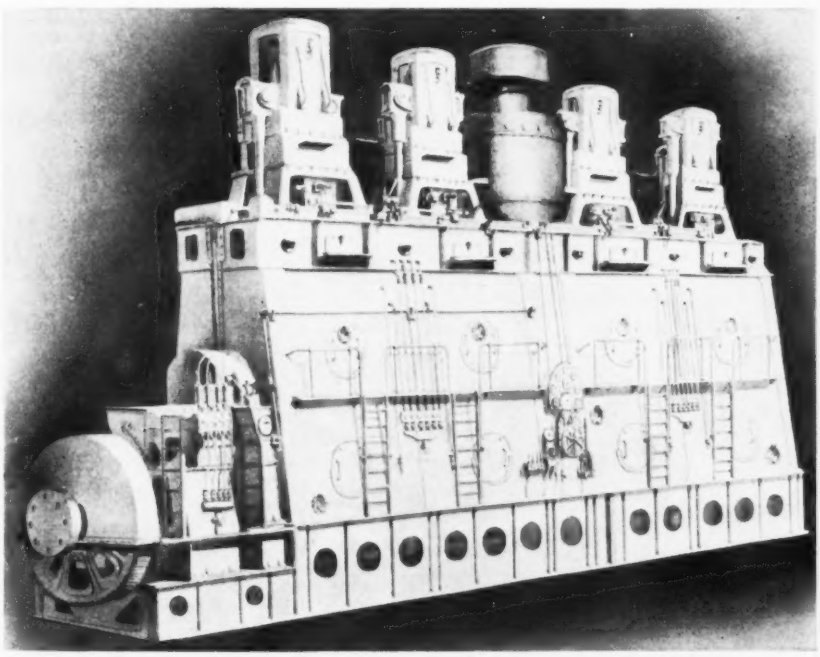
Used Oil Analyses—The lubricating oil should be kept in good condition, this being particularly necessary when the oil from the crankcase also lubricates the cylinders. Dirty or partially oxidized oil obviously is more apt to cause piston deposits than oil in good condition. The analysis of the used oil, while usually made to determine its condition is even more valuable as an indicator of engine operation.

The presence of an excessive proportion of oxidized oil as shown by the analysis may indicate the engine is running too hot, while a high percentage of fuel soot is a sign of poor combustion usually attributed to cold operation.

Iron or bearing metal in the used oil is evidence of rust or wear. If the ash also contains foreign abrasive matter, this is usually assumed to be the cause of wear and the source should be eliminated.

Water may be evidence of a defective cooling system or of condensation from cold operation. Fuel dilution may come from a fuel system leak or it may indicate incomplete combustion, faulty injection, etc.

Deposit Analysis—Typical analyses of the crankcase oil and deposits from the piston skirt and top ring groove of a normally functioning engine are shown in Table XIII. This was a large engine operating on a light distillate fuel and injection nozzles, timing, etc., were properly adjusted. Accordingly, a minimum amount of soot was being formed. Even



Courtesy
Sun Shipbuilding & Dry Dock Company

6,000 HP
4 Cyl.
32x55+40
94 RPM
4 Cycle
Opposed Piston

TABLE XIII

Typical Analyses from Normal Engine

	Crankcase Oil 250 Hours No filter	Deposit from Top Ring Groove	Deposit from Piston Skirt
Oil	99.6%	13%	31%
Carbonaceous	0.1	81	20
Oxidation products	0.0	4	44
Additive Metal	0.3	2	5
Total	100%	100%	100%

so, the reduced additive content and the high carbonaceous percentage show that a considerable portion of the ring groove deposit is soot. The lack of oxidation products in the crankcase oil, which also lubricated the piston, shows that the piston skirt deposit is largely due to oxidation of the oil at that point. Since an abnormal condition may produce an abnormal type of deposit, differing from Table XIII, an analysis may furnish a clue as to its source.

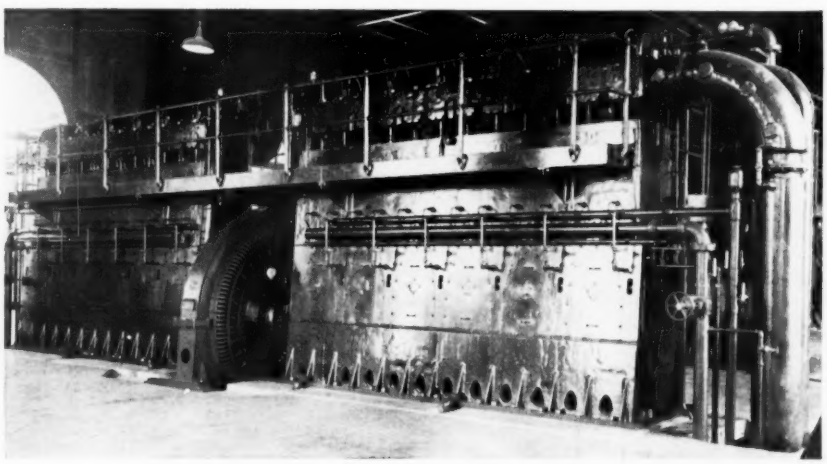
Oil Purification—The contaminants which the various types of purifier remove are shown in table XIV. The degree to which they are removed depends on the size of the purifier. In the selecting of a purifier, therefore, both type and size must be given consideration. In the case of filters, a small filter size can be compensated for by more frequent replacements. Most purifier manufacturers have worked out a set of recommendations based on horse-power, which cover normal operations. Larger purifiers are needed, however, if temperatures or other conditions cause excessive oxidation, or if a lot of power is produced from a small engine, as is the case in highly super-charged four-cycle Diesels where the pressures are high, blow-by is increased and more soot present in the crankcase oil. If a heavy fuel is used, the amount of crankcase contamination with fuel combustion products will be considerable; in fact, the amount may become so great that a combination of purifiers may be necessary. For example, a centrifuge may be used to remove the bulk of the contaminant and a fine filter for final purification.

Clay may be used as a filtering medium even with additive oils, at least in some cases. Table XV gives typical results of a large Diesel operating with a clay filter and a detergent oil compared with a cellulose

TABLE XV

Effect Type Filter on Additive Content Heavy Duty Oil in Large Diesel Having Single Lubrication System

Hours	Additive Content—% Waste Filter	Clay Filter
0	100	100
250	95	23
500	91	50
1000	88	87
2000	88	87



Courtesy Ralphun-Jones Engineering Company

2,460 HP
12 Cyl.
19½x28
257 RPM
4 Cycle

TABLE XIV

Lubricating Oil Contaminants Removed by Purifiers

	Solids	Dissolved Sludge	Water	Fuel
Metallic Filter	X			
Cellulose Filter	X		*	
Fuller's Earth Filter	X	X	*	
Centrifuge	X		X	
Clay Reclaimer	X	X	X	X

*Small quantities.

TABLE XVI

Effect of Temperature and Clay Dosage on Removal of Corrosive Oxidation Products by Reclaiming
(Based on MacCoull test)

Oil	Bearing Test Weight loss, Mg.
New	5
Used	51
Reclaimed at 200°F, 1.0# clay/gal.	26
Reclaimed at 435°F, 0.5# clay/gal.	18
Reclaimed at 435°F, 1.0# clay/gal.	6

TABLE XVII

Effect of Amount of Lead in Bearing Metal on Resistance to Corrosion

	MacCoull Corrosion Test	
% Lead in Bearing Alloy	Mg. Weight Loss, 10 hrs. at 350 °F Heavy Duty Oil	Straight Mineral Oil
0	0	0
92	8	20
96	13	230
100	23	900

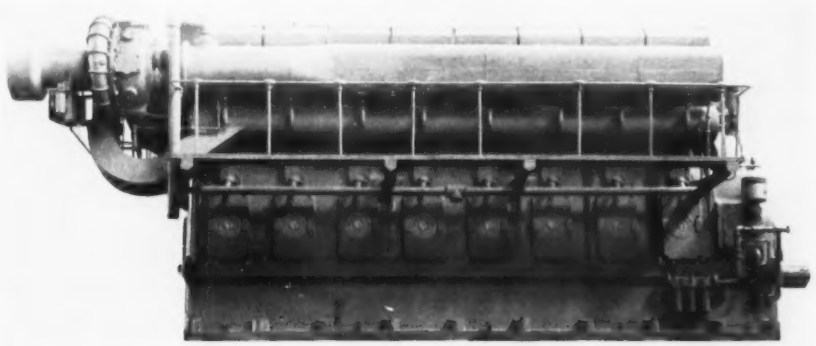
filter on the same operation. The clay filter initially removed the additive, but soon became saturated with respect to the additive, although it remained suitable for removing oil contaminants. As new oil was added to the system, the additive content eventually returned to normal.

There is another point that must be given consideration when using clay with detergent oils, and that is the reduced flow rate. For this reason, clay purifiers are more satisfactory with detergent oils where the oil is not too badly contaminated.

In connection with reclaiming with activated clay, since the clay is so much more effective at high temperatures, the reclaimer should be operated just below the flash point of the oil. The advantage of operating at the elevated temperature with the proper clay dosage is shown in Table XVI. It should be remembered, however, that effective reclaiming can be expected to completely remove the additives present in the used oil.

Bearings. Manufacturers have for years employed tin base babbitt as a standard bearing metal with excellent results, because of its conformability, embeddability and anti-friction properties. Its load carrying ability is definitely limited, however, and other soft metals such as lead hardened by small percentages of arsenic, calcium, silver or copper, are now in general use. As power outputs increased and bearing loads became more concentrated, combinations of various metals have been developed having greater load-carrying ability. These are too numerous to mention but include: babbitt-lined bronze, copper-lead, cadmium-silver, aluminum-tin, lead lined silver and lead-filled silver grid. Each of these bearing metals requires special lubrication treatment and should not be used indiscriminately.

A most important bearing characteristic from a lubrication standpoint is the lead content of any metal exposed to the oil. This is because oxidized oils have a tendency to dissolve lead as illustrated in Table XVII. To avoid so-called oil corrosion, it is advisable to use an alloy of 8-10% tin in lead rather than pure lead as a bearing coating.



Courtesy Chicago Pneumatic Tool Company

1,650 HP
8 Cyl.
16x22
327 RPM
4 Cycle

In selecting an oil for the bearings of a large Diesel it must be remembered that the same oil often serves as a piston coolant and may reach the cylinders in considerable quantity. With these considerations in mind, the crankcase oil viscosity varies from 200 to 300 SSU @ 130° F., the type depending on the purification system employed and the bearing metals involved.

Crankcase Ignition—For a mixture of oil vapor and air to be inflammable, the oil vapor content must be at least 5% and not more than 15% by weight. Sampling of numerous crankcases of both high and low speed Diesels with both vacuum and positive pressures on the crankcase has failed to disclose any

TABLE XVIII

Lubrication Data, Averaged—Large Low Speed Diesels

		American	European
		Busch Hamilton	B&W
Engines		Nordberg	MAN
Cylinder Size		21x28	20x31
RPM		235	180
Strokes per Cycle		2	2
HP/cylinder		370	330
Piston Type		Trunk	Trunk
Bearing Metal Bands on Piston		Yes	Yes
Compression Rings		6	6
Oil Rings		3	2
Cylinder Leads		6	6
Oil Sump Capacity, gal/HP		0.4	1.3
Oil Filter type		Clay	Metal Screen
Crankpin Bearing		Babbitt	Babbitt
Oil Consumption, HPHrs/gal, cyl		6300	6500
brg		5800	6700
Total		3000	3300
Oil Pressure, bearings #/sq. in		25	15
piston #/sq. in		35	15
Bearing Oil Temp °F	in	120	96
	out	130	102
Piston Cooling Oil Temp. °F	in	120	96
	out	135	113
Jacket Water Temp. °F	in	122	95
	out	129	122
Exhaust Temp. full load °F		480	470
Piston Crown depth, in		3	4.5
Cylinder Oil Viscosity SSU @ 210 °F		81	66
Bearing Oil Viscosity SSU @ 130 °F		232	244

appreciable petroleum gases in the engine. Analysis of blow-by gases shows them to be largely air which explains the fact that the crankcase atmosphere is mostly air (with a small percentage of carbon dioxide) in which are suspended fine particles of oil as a mist or fog, but not as a vapor. Experimental evidence indicates that crankcase inflammation is propagated through an atmosphere of fine oil droplets, the mechanism being similar to the spontaneous combustion of coal dust. This sort of atmosphere is more difficult to ignite than a combustible mixture of petroleum vapors in air which seldom exists in a crankcase.

Typical Engine Data—Lubrication data on large two-cycle Diesels are shown in table XVIII, where three each of three different makes of American engines are averaged and compared with two European Diesels of approximately the same bore and stroke. The comparison shows the European engine operating at slower speeds, with fewer oil rings, with larger oil sumps, at lower oil pressures and at lower temperatures.

There is good agreement among the nine American engines on all counts, except in the amount of crankcase make-up oil. This figure varied considerably, even among engines of the same design using the same oil. It appears therefore that crankcase oil consumption is more dependent on engine condition than design.

CONCLUSION

As compared to a high speed Diesel, a large low speed engine requires different lubrication treatment because the oil film is exposed to more heat and circulates more slowly over piston surfaces. To meet these conditions the designer provides oil-cooled pistons and improved methods of distributing oil over the cylinder surface, the operator keeps oil and jacket water temperatures at a comparatively low level and the oil supplier provides a lubricant refined to meet these and other requirements peculiar to the individual engine.

The illustrations accompanying this article include only those American Diesels rated over 200 HP/cyl and under 500 RPM.

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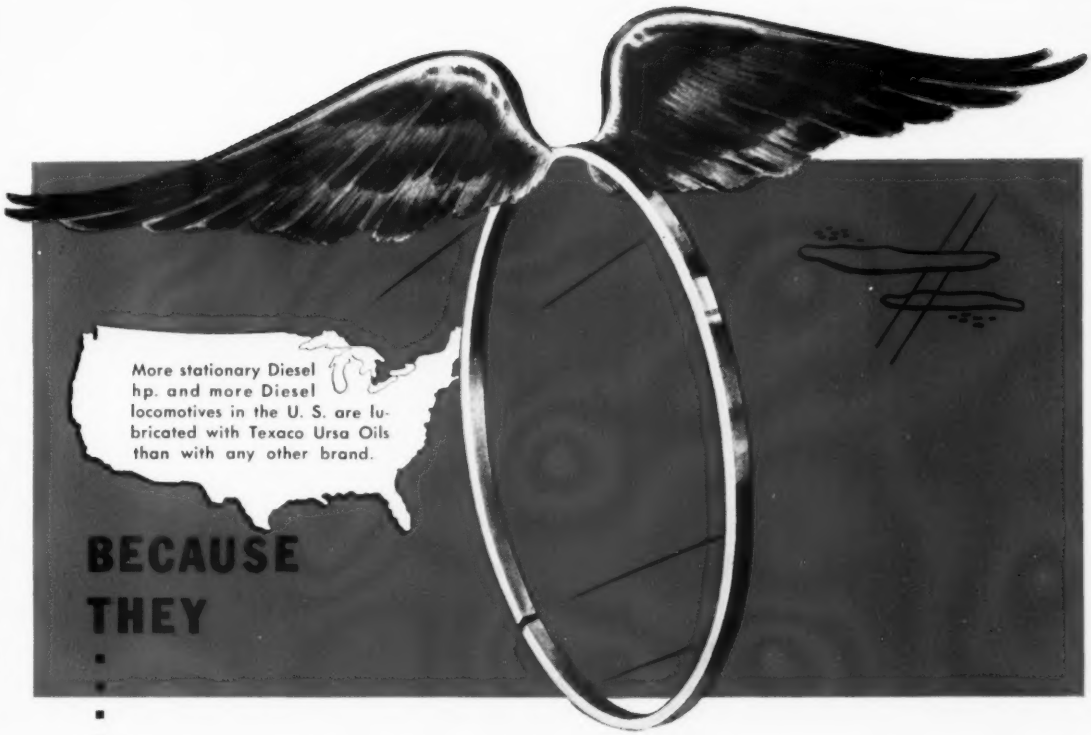
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TEXACO Ursa Oils FOR ALL DIESEL ENGINES

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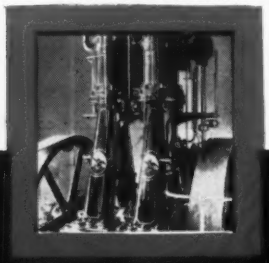

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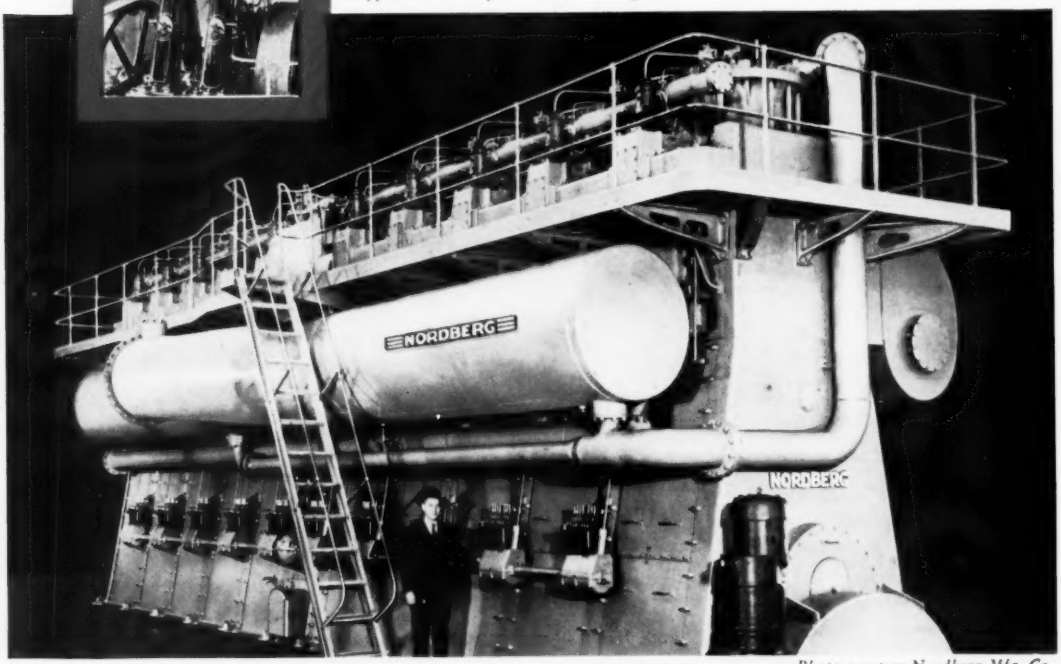

Photo courtesy Nordberg Mfg. Co.

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